



Biomechanical aspects: Summary and consensus statements of group 4. The 5 EAO Consensus Conference 2018

Hämmerle, Christoph H F ; Cordaro, Luca ; Apaza Alccayhuaman, Karol A ; Botticelli, Daniele ; Esposito, Marco ; Colomina, Lino E ; Gil, Alfonso ; Gulje, Felix L ; Ioannidis, Alexis ; Meijer, Henny ; Papageorgiou, Spyridon ; Raghoobar, Gerry ; Romeo, Eugenio ; Renouard, Franck ; Storelli, Stefano ; Torsello, Ferruccio ; Wachtel, Hannes

Abstract: **OBJECTIVES** The aim of the present publication was to report on the EAO Workshop group-4 discussions and consensus statements on the five reviews previously prepared. These reviews provided the scientific evidence on the effect of crown-to-implant ratio, on reconstructions with cantilevers in fully and partially edentulous patients, on biological and technical complications of tilted in comparison with straight implants, and on the effects of osseointegrated implants functioning in a residual dentition. **MATERIAL AND METHODS** The group discussed, evaluated, corrected where deemed appropriate, and made recommendations to the authors regarding the following five reviews submitted: (a) Is there an effect of crown-to-implant ratio on implant treatment outcomes?; (b) Implant-supported cantilevered fixed dental rehabilitations in fully edentulous patients; (c) and in partially edentulous patients; (d) Biological and technical complications of tilted implants in comparison with straight implants supporting fixed dental prostheses; (e) What are the adverse effects of osseointegrated implants functioning among natural teeth of a residual dentition? Based on the five manuscripts and the discussion among the group as well as the plenum members, the major findings were summarized, consensus statements were formulated, clinical recommendations were proposed, and areas of future research were identified. **RESULTS** Crown-to-implant ratios ranging from 0.9 to 2.2 did not influence the occurrence of biological or technical complications also in single-tooth restorations. Reconstructions with cantilevers for the rehabilitation of fully and partially edentulous jaws showed high implant and reconstruction survival rates. In contrast, the rate of complications-in particular associated with veneering material-was high during the observation period of 5-10 years. The data reported were primarily derived from studies with high risk of bias. The data for single-implant reconstructions were small. There was no evidence that distally tilted implants were associated with higher failure rates and increased amounts of marginal bone loss. The data supporting these findings, however, were at high risk of bias and frequently incompletely reported. Frequent positional changes occurred between the natural teeth and the implant-supported restorations. These changes were more pronounced in younger individuals, and even though they were reduced with age, they still occurred in adult patients. Even though these changes were frequent, potential implications for the patient are unclear. **CONCLUSIONS** The use of single-tooth restorations with crown-to-implant ratio in between 0.9 and 2.2 may be considered a viable treatment option. Multiunit reconstructions with cantilevers are a viable treatment option in fully and partially edentulous patients. Clinicians and patients should be aware, however, that complications are frequent and primarily related to resin material used for veneering. There is some evidence that tilting an implant does affect stability of the implant and the surrounding bone. Treatment options to tilted implants should carefully be considered, as the effect on soft tissues and on prosthesis behavior is poorly reported for tilted implants. Positional changes in the dentition in relation to implant-supported restorations occur frequently. The patient should be informed about the possible need for a treatment related to these changes in the long term.

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Biomechanical aspects: Summary and consensus statements of group 4. The 5th EAO Consensus Conference 2018

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Abstract

Objectives: The aim of the present publication was to report on the EAO Workshop group-4 discussions and consensus statements on the five reviews previously prepared. These reviews provided the scientific evidence on the effect of crown-to-implant ratio, on reconstructions with cantilevers in fully and partially edentulous patients, on biological and technical complications of tilted in comparison with straight implants, and on the effects of osseointegrated implants functioning in a residual dentition.

Material and Methods: The group discussed, evaluated, corrected where deemed appropriate, and made recommendations to the authors regarding the following five reviews submitted: (a) Is there an effect of crown-to-implant ratio on implant treatment outcomes?; (b) Implant-supported cantilevered fixed dental rehabilitations in fully edentulous patients; (c) and in partially edentulous patients; (d) Biological and technical complications of tilted implants in comparison with straight implants supporting fixed dental prostheses; (e) What are the adverse effects of osseointegrated implants functioning among natural teeth of a residual dentition? Based on the five manuscripts and the discussion among the group as well as the plenum members, the major findings were summarized, consensus statements were formulated, clinical recommendations were proposed, and areas of future research were identified.

Results: Crown-to-implant ratios ranging from 0.9 to 2.2 did not influence the occurrence of biological or technical complications also in single-tooth restorations. Reconstructions with cantilevers for the rehabilitation of fully and partially edentulous jaws showed high implant and reconstruction survival rates. In contrast, the rate of complications—in particular associated with veneering material—was high during the observation period of 5–10 years. The data reported were primarily derived from studies with high risk of bias. The data for single-implant reconstructions were small. There was no evidence that distally tilted implants were associated with higher failure rates and increased amounts of marginal bone loss. The data supporting these findings,

however, were at high risk of bias and frequently incompletely reported. Frequent positional changes occurred between the natural teeth and the implant-supported restorations. These changes were more pronounced in younger individuals, and even though they were reduced with age, they still occurred in adult patients. Even though these changes were frequent, potential implications for the patient are unclear.

Conclusions: The use of single-tooth restorations with crown-to-implant ratio in between 0.9 and 2.2 may be considered a viable treatment option. Multiunit reconstructions with cantilevers are a viable treatment option in fully and partially edentulous patients. Clinicians and patients should be aware, however, that complications are frequent and primarily related to resin material used for veneering. There is some evidence that tilting an implant does affect stability of the implant and the surrounding bone. Treatment options to tilted implants should carefully be considered, as the effect on soft tissues and on prosthesis behavior is poorly reported for tilted implants. Positional changes in the dentition in relation to implant-supported restorations occur frequently. The patient should be informed about the possible need for a treatment related to these changes in the long term.

KEYWORDS

biomechanics, clinical research, clinical trials, finite element analysis, prosthodontics

1 | IS THERE AN EFFECT OF CROWN-TO-IMPLANT RATIO ON IMPLANT TREATMENT OUTCOMES? A SYSTEMATIC REVIEW

1.1 | Major findings from the review

The meta-analysis on nonsplinted implant-supported single-tooth restorations with increased crown-to-implant ratio after a mean observation time ranging from 12 to 74 months including eight studies demonstrated high survival rates of the implants and small mean marginal bone loss (Meijer, Boven & Raghoobar, 2018). Scarce evidence could be retrieved on whether different increased crown-to-implant ratios have an influence on the former outcomes. The few papers describing technical complications showed a small number of adverse events.

1.2 | Consensus statements

Previous reviews have demonstrated negligible effects of crown-to-implant ratio on biological complications when short implants are splinted. A crown-to-implant ratio ranging from 0.9 to 2.2 seems not to influence the occurrence of biological or technical complications also in single-tooth restorations. These findings, involving various dental implant systems, should not be extrapolated to larger ratios. Most of the data reported are related to implants of reduced length. There is no clear information on whether distal-end restorations perform in a different way than the ones in between two dental units.

1.3 | Clinical recommendations

In cases of reduced vertical bone dimensions and increased interocclusal space, the use of single-tooth restorations with crown-to-implant ratio in between 0.9 and 2.2 is not expected to increase the failure rate and may be considered a viable treatment option. This is also the case when a short implant (6–8 mm in length) with standard diameter is to be inserted. This option may reduce the need for bone augmentation procedures.

1.4 | Recommendations for future research

Prospective randomized long-term studies should be performed aimed at comparing the use of short implants supporting a restoration that compensates the increased interocclusal space, with longer implants placed after bone augmentation procedures to correct the increased interocclusal space and then restored with a reconstruction of normal dimensions. Studies should separately report on maxillary and mandibular data, as different bone densities are predominant and may influence outcomes.

2 | IMPLANT-SUPPORTED CANTILEVERED FIXED DENTAL REHABILITATIONS IN FULLY EDENTULOUS PATIENTS: SYSTEMATIC REVIEW

2.1 | Major findings from the review

High prosthesis survival rates (97%) were reported for full-arch reconstructions exhibiting cantilevers (Storelli, Del Fabbro, Palandrani,

& Romeo, 2018). The survival rate of the implants supporting these prostheses amounted to 99%. These data are derived from seven prospective and seven retrospective studies analyzing 625 prostheses supported by 2,888 implants in 558 patients. Four studies were rated as moderate and 10 as high risk of bias. The studies covered mean follow-up periods ranging from 5 to 10 years. When the length of the cantilevers was reported, a maximum of two teeth or 20 mm of occlusal surface were replaced.

A total of 44% patients were suffered from complications, whereas 39% of the restorations were affected.

The majority of the complications were chippings or fractures of the veneering material (26%). When analyzing the dataset with respect to the veneering material used, nine studies could be identified dealing with this issue. Seven studies with resin veneering analyzed 269 reconstructions and reported a complication rate of 37%. The two studies with ceramic veneering analyzed 65 reconstructions and obtained a complication rate of 4%. Screw loosening amounted to 5%, abutment and screw fracture to 4%, and framework fracture to 3%.

For the reconstructions, a biological complication rate of 16% was reported and for the implants, it amounted to 3%. The complications reported were peri-implant mucositis and peri-implantitis.

2.2 | Consensus statements

Reconstructions with cantilevers for the rehabilitation of fully edentulous jaws showed high survival rates. In the same way, the survival rate of the implants supporting the reconstructions was very high. In contrast, the rate of complications – primarily chipping and fracture of veneering material – was high during the observation period of 5–10 years.

The biological and technical complications addressed in the present review were not reported in all studies. Based on this, the interpretation of the data needs to be carried out with caution. The true figures for complications may be higher due to underreporting or due to confirmation bias.

The data available are limited to cantilevers replacing no more than two occlusal units or 20 mm of occlusal distance.

For the treatment of edentulous jaws, treatment concepts exist other than cantilever fixed reconstructions. The review failed to identify RCTs or controlled studies comparing different treatment concepts.

2.3 | Clinical recommendations

Based on the present data, the concept of fixed reconstructions with cantilevers for the rehabilitation of edentulous jaws can be recommended as a viable treatment option rendering high survival rates for reconstructions and implants. Clinicians and patients should be aware, however, that complications are frequent and primarily related to resin material used for veneering.

The results of the present study cannot be applied to cantilevers of higher length than the ones reported in the present review.

2.4 | Recommendations for future research

Future research should address the following questions ideally also assessing patient-reported outcome measures:

- How do full-arch reconstructions with end abutments perform compared to distal cantilevers?
- How do bone augmentation procedures with subsequent implant placement perform compared to cantilevers?
- How do tilted implants with reduced cantilever length perform compared to straight implants with longer cantilevers?
- Are there materials superior to others regarding manufacturing and clinical performance for cantilevered full-arch reconstructions?

3 | IMPLANT-SUPPORTED CANTILEVERED FIXED DENTAL REHABILITATIONS IN PARTIALLY EDENTULOUS PATIENTS: SYSTEMATIC REVIEW

3.1 | Major findings from the review

High prosthesis survival rates (98%) were reported for multiunit fixed reconstructions exhibiting cantilevers (Storelli, Del Fabbro, Palandrani, & Romeo, 2018). The survival rate of the implants supporting these prostheses amounted to 98%. These data are derived from four prospective and five retrospective studies analyzing 376 prostheses supported by 739 implants in 349 patients. Eight of the studies were at high and one at moderate risk of bias. The studies covered mean follow-up times ranging from 5 to 18 years. The majority of the cantilevers ranged in length from 6 mm to two occlusal units. Both mesial and distal cantilevers were included replacing anterior and posterior teeth.

A total of 29% of patients were suffered from complications, whereas 27% of the reconstructions were affected.

The majority of the complications were chippings or fractures of the veneering material (14%) always supported by metal frameworks. In the majority of studies, ceramic was used as the veneering material. Screw loosening amounted to 5%, loss of retention to 5%, and abutment and screw fracture to 2%. The mode of retention encompassed both screw and cement type. No framework fracture was reported. Implant fractures occurred in 0.3% of implants.

Only four studies reported on peri-implantitis. It affected 6% of the reconstructions and 4% of the implants.

High prosthesis survival rates (97%) were reported for single implants supporting one crown and one cantilever. The survival rate of the implants supporting these prostheses amounted to 98%. These data are derived from two retrospective studies analyzing 44 prostheses supported by 44 implants in 42 patients. The studies reported mean follow-up times of 6 and 14 years. One study reported

a mean length of the cantilever of 10 mm. Both mesial and distal cantilevers were included. Both studies were at high risk of bias.

The data on complications were too scarce to report any significant findings.

3.2 | Consensus statements

Multiunit implant reconstructions with cantilevers exhibit high survival rates. During the mean observation periods of 5–18 years, a high amount of complications—mainly technical—occurred. This is based on a reasonable amount of data, albeit reported in studies with high risk of bias.

The data pool for single-implant reconstructions with a cantilever is small and also derived from studies with a high risk of bias. No valid information regarding the occurrence of complications could be gathered from the literature.

For both the single and the multiunit reconstructions, cantilevers had replaced teeth mesial or distal to the implants.

3.3 | Clinical recommendations

Based on the present data, the concept of multiunit fixed reconstructions with cantilevers can be recommended as a viable treatment option rendering high survival rates for reconstructions and implants. Clinicians and patients should be aware, however, that this recommendation is based on few studies.

For single-implant reconstructions with cantilevers, the data available are promising but so scarce that the procedure cannot be recommended for routine clinical use.

It appears that cantilevers can be used to replace teeth either mesial or distal to the implant/s.

The results of the present study should only be applied to cantilevers of equal or lower length compared to the ones reported in the present review.

3.4 | Recommendations for future research

Future research should address the following questions ideally also assessing patient-reported outcome measures:

- How do multiunit reconstructions perform with and without cantilevers in different clinical situations?
- How do multiunit reconstructions with cantilevers perform compared to multiunit reconstructions with end abutments?
- How do bone augmentation procedures with subsequent implant placement perform compared to cantilever reconstructions?
- How do single implants with cantilevers perform compared to two adjacent implants with single crowns in the esthetic or in the nonesthetic area?
- Are there materials superior to others regarding manufacturing and clinical performance for cantilevered multiunit and single-implant reconstructions?

- Are there implant materials or implant designs/dimensions superior to others for cantilevered multiunit and single-implant reconstructions?
- How do cantilevers of different dimensions perform?

4 | BIOLOGICAL AND TECHNICAL COMPLICATIONS OF TILTED IMPLANTS IN COMPARISON WITH STRAIGHT IMPLANTS SUPPORTING FIXED DENTAL PROSTHESES. A SYSTEMATIC REVIEW AND META-ANALYSIS

4.1 | Major findings from the review

The reported evidence is based on 17 cohort studies (eight prospective and nine retrospective, mostly large-scale, and mostly with serious risk of bias) including 1,849 patients with 7,568 implants and 1,656 full-arch or short-span fixed restorations (Apaza Alccayhuaman, et al., 2018). Following an observation of 3–5 years, no detrimental effect on survival rate or marginal bone loss of tilted implants was observed, when compared to straight ones. This confirmed what has been reported by previous systematic reviews with follow-up time up to 1 year. By bad luck, the status of peri-implant soft tissues was not thoroughly reported. Methodological constraints did not permit to evaluate the influence of implant angulation on the prosthetic complications.

4.2 | Consensus statements

Implant angulation is usually measured in the mesiodistal dimension in relation to a vertical axis perpendicular to the occlusal plane. Buccal inclination of the implants, that could clinically occur, is not routinely evaluated as a separate risk factor.

There is no evidence that using distally tilted implants one increases the amount of marginal bone loss or the risk of failure of the implant per se at least in the mid-term. It should be noted that identified retrospective studies showed a potentially biased effect of implant inclination on implant survival compared to prospective studies. Evidence is lacking whether tilted implants have a negative impact on peri-implant soft tissues or on prosthetic complications; as a consequence, no conclusions can be drawn in this respect.

4.3 | Clinical recommendations

Evidence that tilting an implant is not affecting stability of the implant, and the surrounding bone does not exclude clinical limitations, as the effect on soft tissues and on prosthesis behavior is poorly reported. Even though a tilted implant may be considered a viable option, when used to overcome important anatomical limitations, treatment options such as the use of straight implants and reduced extent of the cantilever or augmentation procedures should carefully be evaluated in the treatment plan. In this context, it is emphasized

that the treatment plan should be based on the individual needs of the patient.

4.4 | Recommendations for future research

- There is a need to monitor the effects of distally tilted implants on prosthetic complications and on peri-implant soft tissues.
- Randomized controlled studies comparing solely straight implant-supported restorations with ones supported also by tilted implants should be performed.
- A comparison of tilted implants with straight implants with bone augmentation is also suggested.
- Further studies looking at the effects of implant inclinations also in buccal/oral directions should be performed as most of the existing literature focused mainly on soft tissue recession.

5 | WHAT ARE THE ADVERSE EFFECTS OF OSSEOINTEGRATED IMPLANTS FUNCTIONING AMONG NATURAL TEETH OF A RESIDUAL DENTITION? A SYSTEMATIC REVIEW WITH META-ANALYSIS

5.1 | Major findings from the review

The review focused on the frequency of infraposition and missing contact points in implant-supported restorations within natural dentitions over time (Papageorgiou, Eliades, & Hämmeler, 2018).

Of the data reported in 27 cohort studies, the majority of which were retrospective, 1,367 patients and 1,993 implants could be included in the meta-analysis.

Evidence indicates that infraposition (IIP) or missing proximal contact points (PCP) occur in half of the implant-supported restorations analyzed in this review after a mean follow-up of 5.7 years (range 1–18 years).

The amount of IIP varied greatly with only 21% of the restorations showing more than 1 mm of IIP. Missing PCP was seen every second restoration. IIP and PCP increase over time. IIP is more frequent among females. PCP occurs more often at the mesial side of the restorations. The older the patient at the time of treatment, the smaller the IIP observed.

Confidence in the present findings is low due to methodological limitations and the risk of bias of the included studies. No accurate prediction can be made about the frequency and extent of the phenomena on a case-by-case basis.

5.2 | Consensus statements

Frequent positional changes occur between the natural teeth and implant-supported restorations. These changes are more pronounced in younger individuals and even though reducing with age may still occur in adult patients (e.g., 30 years and older). Even though these changes are frequent, potential implications for the patient are unclear.

5.3 | Clinical recommendations

Positional changes in the dentition in relation to implant-supported restorations occur but have rarely been reported in regard to the clinical implications. They should be monitored, and the patient should be informed about the possible need for a treatment related to these changes in the long term. The clinician should carefully consider these potential changes in the treatment-planning phase, especially in young patients but also in adults of any age, with respect to the tendency of these changes to reduce with age. Esthetic and functional implications should be taken into consideration.

5.4 | Recommendations for future research

- Positional changes of the residual dentition in relation to implant-supported restorations need to be evaluated in individuals of different ages with large-scale prospective studies of adequate duration possibly including control groups.
- The clinical implications for the patient and the dentist need to be further evaluated including also technical, biological, esthetic, and patient-reported parameters.
- Monitoring the clinical situation of the restoration and the dentition at baseline and during follow-up examinations should be performed with precise and repeatable methods (e.g., a full-arch digital scan).
- Specific and precise information on the incidence and severity of the clinical changes should be gathered.
- Additional parameters should be evaluated including gender, age, region of the jaw, extent of the implant-borne reconstruction, periodontal status of the remaining dentition.

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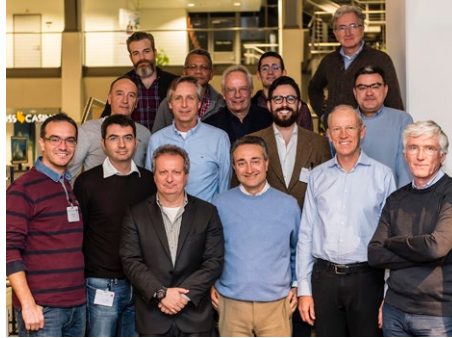
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From left to right, starting from the top: Alexis Ioannidis, Gerry M. Raghoobar, Spyridon N. Papageorgiou, Felix Guljé, Lino Esteve Colomina, Henny J. Meijer, Hannes Wachtel, Alfonso Gil, Eugenio Romeo, Stefano Storelli, Ferruccio Torsello, Marco Esposito, Luca Cordaro, Christoph Hämmeler, Franck Renouard

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